Classification of topsoil structural quality with physical thresholds

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Soil structure quality is increasingly threatened and must be protected by environmental regulations. However, this is not done, so far, because no indicators and corresponding classification scheme for harmful versus acceptable conditions fulfilled the many necessary conditions. The aim of this study was to solve this issue. We used shrinkage curve analysis for precise physical measurements allowing to cope with field constituents and water content variability, and visual evaluation yielding scores from 1 (good) to 5 (poor) to define a structure quality classification scheme. We characterized 185 undisturbed samples, collected from 162 sites at 5-10 cm depth on a unique soil type, Cambi-Luvisol, across western Switzerland. We found that structural porosity and soil organic carbon content (SOC) were the most discriminant indicators to classify the visual scores (Figure 1). The good score values (1-2.5) corresponded to significant correlations of structural porosity and SOC, thus the structure quality could be classified with structural porosity volume provided that SOC was taken into account: the larger the SOC, the larger must be the structural porosity for equivalent structure quality.
Additionally, because SOC and clay content are correlated, more SOC is needed to reach a good structure quality when clay content increases. This is in close agreement with the findings of Feller & Beare (1997) and Johannes *et al.* (2017). Therefore, an improved soil structure quality can be achieved in two steps. First by targeting an optimal value of SOC which depends on clay content. Secondly by targeting an optimal physical value which depends on SOC, as presented in Figure 1.

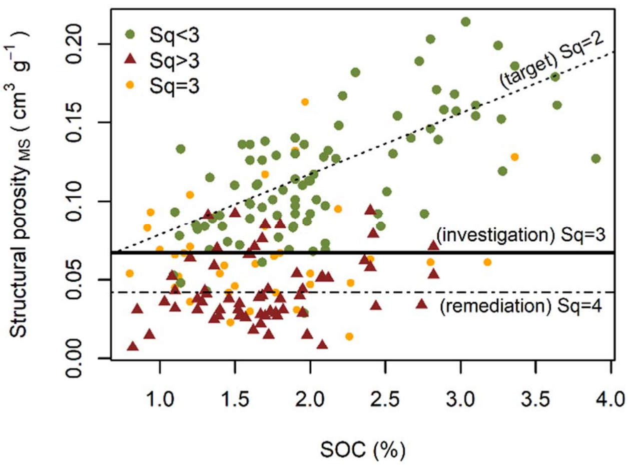

Figure 1: Structural porosity at maximum swelling point (MS) as a function of soil organic carbon (SOC) with target values (dotted line), investigation threshold (full line) and remediation threshold (dashed line) and with observations of good structural quality (Sq<3, represented by full green dots), medium structural quality (Sq=3, represented by full yellow dots) and poor structural quality (Sq>3, represented by red triangles).

The gravimetric air content at -100 hPa (A_{-100}) was highly correlated to structural porosity (R^2 0.95) and the gravimetric water content at -100 hPa (W_{-100}) was highly correlated to SOC (R^2 0.72). These two indicators are easy and inexpensive to measure which is an important aspect in the application for environmental regulations. Therefore, for application purposes we suggested to use A_{-100} instead of structural porosity and W_{-100} instead of SOC to classify soil structure quality. With respect to the threshold limit of structure quality score 3 departing damaged and acceptable structure, A_{-100} and W_{-100} classified soil structure quality well and there was a significant correlation of A_{-100} to W_{-100} for soils with good structure quality. Therefore, the proposed classification scheme uses the relationships between A_{-100} and W_{-100} for scores 2, 3, and 4 as target, investigation and remediation values, respectively (Table 1).

Table 1: Limit values of gravimetric air content at -100 hPa and their interpretation. (Adapted from a table submitted to Ecological Indicators Journal)

Limit value	A_{-100}	Corresponding CoreVESS score	Interpretation
Target	$0.023 + 0.288 \times W_{-100}$	Sq=2	A guide value for soil management. Healthy soils should be above this value.
Investigation	0.068 $cm^3 g^{-1}$	Sq=3	Value below which the reasons for the poor soil structure quality should be investigated and soil management must be adapted to improve structure quality.
Remediation	0.045 $cm^3 g^{-1}$	Sq=4	Short term improvements of soil structure quality are needed.

A_{-100}: Gravimetric air content at -100 hPa (cm^3 g^{-1}); W_{-100}: Gravimetric water content at -100 hPa (g g^{-1})

This method classified 91% of the "poor" structures under the investigation limit and 92% of the "good" structures above the investigation limit. This improves sharply the correctness of classification compared to previous indicators and can be proposed for soil structure protection regulation. Further research is needed to develop structural quality threshold values for subsoil and other soil types.

References

Feller, C. & Beare, M.H. 1997. Physical control of soil organic matter dynamics in the tropics. *Geoderma*, **79**, 69–116.
Johannes, A., Matter, A., Schulin, R., Weisskopf, P., Baveye, P.C. & Boivin, P. 2017. Optimal organic carbon values for soil structure quality of arable soils. Does clay content matter? *Geoderma*, **302**, 14–21.